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RESEARCH AND DEVELOPMENT OF THE 800 HZ BARREL-STAVE FLEXTENSIONAL TRANSDUCER AT THE DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

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Dennis F. Jones

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Approved by H. Merklinger
Director General

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Abstract

The Defence Research Establishment Atlantic (DREA) barrel-stave flextensional transducer is a compact underwater sound source that is well-suited for high-power low-frequency sonar applications. Various configurations of this transducer were modelled in the 1980s using finite element analysis techniques. A scaled-up version of one of these models was used to design an 800 Hz barrel-stave transducer prototype that was built and tested in 1991. Good performance parameters were obtained for the prototype and by 1996 a number of additional units were built for in-house research purposes. Some of these transducers have performed flawlessly during many DREA sea trials over the last five years. More comprehensive measurements and modelling analyses were done on the 800 Hz prototype through international collaborations with researchers at the Naval Undersea Warfare Center in New London, CT (now consolidated in Newport, RI), and Weidlinger Associates Incorporated in New York, NY. Since the measured acoustic performance parameters for the 800 Hz experimental transducers compare well with the parameters of commercially available piezoelectric flextensional transducers, the technology was transferred to Sparton of Canada Limited in 1996 and has been designated Sparton Model 06BA0800. In the same year, the Model 06BA0800 was sold to the Defence Science and Technology Organisation in Australia as one of four active sources in a broadband deployable sonar system known as the Sonar Research Projector towbody. The purpose of this report is to document the history of this flextensional transducer by assembling a mosaic of examples from the various research and development activities that have taken place since 1991.

Résumé

Le transducteur flextensionnel à douves du Centre de recherches pour la défense (Atlantique) (CRDA) est une source acoustique sous-marine compacte qui convient bien pour les applications sonar basse fréquence à puissance élevée. Diverses configurations de ce transducteur ont été modélisées dans les années 1980 au moyen des techniques d'analyse par éléments finis. Une version à l'échelle d'un des modèles réalisés a été utilisée pour concevoir un prototype de transducteur à douves de 800 Hz, qui a été construit et mis à l'essai en 1991. On a obtenu de bons paramètres de performance pour le prototype, et en 1996 un certain nombre d'appareils additionnels avaient été construits à des fins de recherche interne. Certains de ces transducteurs ont fonctionné sans faille dans un grand nombre d'essais effectués en mer par le CRDA au cours des cinq dernières années. Des mesures et des analyses de modélisation plus approfondies ont été effectuées sur le prototype de 800 Hz dans le cadre de projets de collaboation internationale avec des chercheurs du Naval Undersea Warfare Center de New London (CT), aujourd'hui établi à Newport (RI), et de la société Weidlinger Associates Incorporated de New York (NY). Comme les paramètres de performance acoustique mesurés pour les transducteurs expétimentaux de 800 Hz sont comparables aux paramètres de transducteurs flextensionnels piézoélectriques offerts sur le marché, la technologie a été transférée à la société Sparton of Canada Limited en 1996, et on a désigné l'appareil produit comme étant le modèle 06BA0800 de Sparton. La même année, le modèle 06BA0800 a été vendu à la Defence Science and Technology Organisation (Organisation des sciences et technologies pour la défense) en Australie comme l'une des quatre source actives du système sonar déployable à large bande, appelé le poisson remorqué "Sonar Research Projector" (projecteur de recherche sonar). Le présent rapport vise à documenter l'historique de ce transducteur flextensionnel en créant une mosaique d'exemples à partir de diverses activités de recherche et développement réalisées depuis 1991.

Executive Summary

Report Number:

DREA Report 98/101

Title:

Research and Development of the 800 Hz Barrel-Stave Flextensional Transducer at the Defence Research Establishment Atlantic

Author:

D.F. Jones

Background:

Conceived by Jones and McMahon in 1986 and patented in Canada and the United States by 1991, the barrel-stave flextensional transducer is an underwater sound source that has been investigated at the Defence Research Establishment Atlantic (DREA) for high-power, low-frequency active sonar applications. Since the barrel-stave flextensional transducers of the 1980s were designed for operation in the 1-2 kHz frequency range, there was a need for a transducer that operated at frequencies below 1 kHz, but was small, lightweight, and easily handled. The 800 Hz barrel-stave flextensional transducer, scaled up from the early higher frequency designs, filled this need.

Results:

The 800 Hz transducer has been the subject of both in-house research and development and international collaboration over the last six years. Since the construction and testing of the first experimental unit in 1991, the 800 Hz barrel-stave transducer has become an important research tool for many sea-going scientists and engineers at DREA. The measured electroacoustic performance parameters for this transducer are among the best results achieved for barrel-stave flextensional transducers reported to date, and they are comparable to those of other well-established commercial flextensional transducers.

Significance:

The 800 Hz barrel-stave flextensional transducer technology was transferred to Sparton of Canada Ltd. in 1996 and is now commercially available as Sparton Model 06BA0800. This transducer has been sold to the Department of Defence in Australia and has already had a positive impact on their low frequency active sonar research programs.

Future Plans:

With the technology transfer to Sparton of Canada Ltd. successfully completed, future successes of the commercial 800 Hz barrel-stave transducer hinge mainly on the sonar transducer needs of both the international defence and oceanographic communities. This underwater transducer will likely continue to be used as a low frequency research sound source at DREA in the years to come.

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1. Introduction

The 800 Hz barrel-stave flextensional transducer is a compact, high-power, low-frequency, underwater sound source conceived, researched, and developed at the Defence Research Establishment Atlantic (DREA). Its electroacoustic performance epitomizes high-performance piezoceramic-driven flextensional transducer designs, the salient factor that has lead to the success of this device. Several units have been built and tested since 1991 and some of them have played important roles in international collaborations and sea trials in Canada, the United States, and Australia. This DREA sonar transducer has been made commercially available through a technology transfer to industry in 1996.

Based on barrel-stave flextensional designs with resonance frequencies above 1 kHz, the 800 Hz transducer evolved from a sophisticated computer model to an experimental prototype and finally to a commercial product. Years of in-house underwater acoustics research at DREA plus the recent sale of one of these transducers to the Defence Science and Technology Organization in Australia have provided this transducer with a rich research and development history. Therefore, the matter of documenting the evolution of this transducer is timely and constitutes the purpose of this report.

Section 2 presents a brief historical account of the evolution of the barrel-stave flextensional transducer. Section 3 describes the design of the 800 Hz DREA prototype and gives its measured electroacoustic performance. The measured performance parameters of other 800 Hz DREA units are also summarized. The techniques that have been used to deploy this transducer at sea for in-house underwater research are illustrated. Section 4 gives an overview of collaborative measurements and modelling on this transducer by DREA and outside agencies. The commercialization of this transducer is discussed in Section 5 along with a description of an Australian towbody containing one of these 800 Hz units. Finally, a summary that restates the highlights is given in Section 6.

2. Historical Remarks

The flextensional transducer is an audible underwater sound source with a history that predates World War II. The flextensional concept was first described by Harvey Hayes in his 1936 US Patent [1] which included a number of flextensional designs intended for aeroacoustic applications. His elegant explanation of the operating principles underlying this type of transducer remains a starting point for all flextensional transducer designers.

Although these early aeroacoustic flextensional transducers saw limited use at the time, it was not until the 1960s in the midst of the Cold War that flextensional transducers became important for underwater naval sonar applications. A number of flextensional designs were conceived during this decade. One of these designs was the predecessor of the modern day barrel-stave flextensional transducer and appeared in a 1966 US Patent by Merchant [2]. A sketch of this slotted-shell transducer is shown in Figure 1a. The shell is driven into flexure by an internal piezoelectric ceramic driver stack.

An experimental Merchant slotted-shell flextensional transducer was built and tested at DREA in the late 1970s by Armstrong and McMahon [3]. This transducer was modelled using newly emerging electroelastic finite element techniques and the measured acoustic performance was predicted with reasonable accuracy. At its fundamental flexural resonance frequency of 1250 Hz, this transducer could produce a field-limited source level of 190 dB//1μPa-m with an electroacoustic efficiency of 40%. Its mass was 2.5 kg.

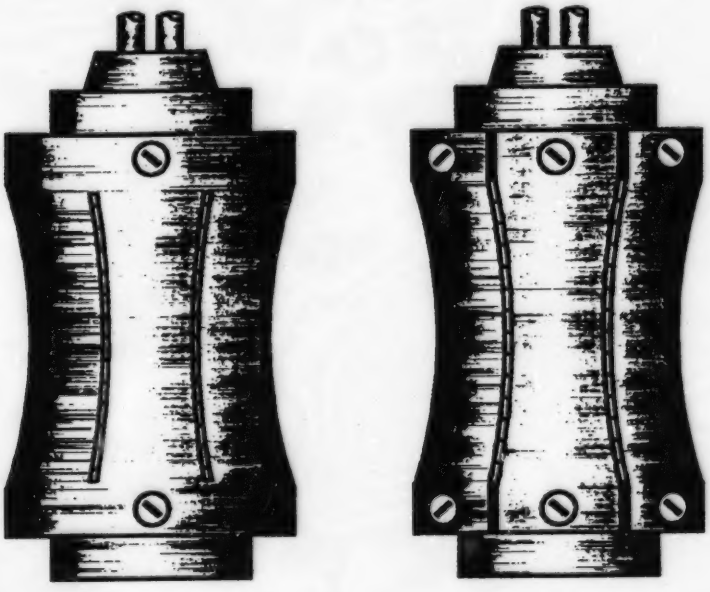

Figure 1. The (a) slotted-shell and (b) barrel-stave flextensional transducers.

The Merchant slotted-shell was replaced by eight curved staves in a modified design by Jones and McMahon [4] in the mid 1980s. This modification is illustrated in Figure 1b. Rubber boots (not shown) are required to seal both transducers from seawater ingress. This experimental barrel-stave flextensional transducer was also designed with a finite element model. It had a mass of 1.9 kg, a resonance frequency of 1150 Hz, a field-limited source level of 194 dB//1μPa-m, and an electroacoustic efficiency of 58%. Patents for the barrel-stave flextensional transducer were filed in 1988 by McMahon and Jones [5] and granted in the spring of 1990 in the United States and in the summer of 1991 in Canada.

By 1991, an 1100 Hz experimental DREA barrel-stave flextensional transducer design was transferred to Sparton of Canada Limited and became commercially available as Sparton Model 03BA1100 [6]. This 1100 Hz commercial transducer had a mechanical quality factor of 5.5, a field-limited source level of 194 dB//1μPa-m at resonance, and an electroacoustic efficiency of 74% at resonance. The completely assembled transducer had a mass of 2.0 kg.

Motivated by the need for DREA researchers to have a powerful but relatively easy-to-handle transducer to use below 1 kHz, a larger version of the barrel-stave flextensional transducer described above was developed in the early 1990s. This transducer, with a flexural resonance frequency of about 800 Hz, acheived the best performance of any barrel-stave flextensional transducer to that date; i.e., 1991. The following sections of this report discuss some of the work that was done on this low-frequency, high-power, and efficient sonar transducer. This includes in-house and collaborative research, as well as the technology transfer to industry in 1996.

3. In-House Research

A concentrated effort to numerically model barrel-stave flextensional transducers using the 2D finite element program MAVART took place from 1986 to 1990. MAVART, an acronym for Model for the Analysis of Vibrations and Acoustic Radiation of Transducers, is capable of modelling axisymmetric piezoceramic transducers radiating into an acoustic fluid. During this period, many configurations were explored that produced flexural resonance modes in the 1-2 kHz frequency range. Some of these computer designs were used to build prototype transducers that were calibrated in water at DREA [7].

A portion of a finite element mesh for one such design is shown in Figure 2. Note that the full quarter cross-section mesh includes additional seawater elements (not shown) that extend out to a circular boundary whose diameter is approximately three times the length of the transducer. Modelled are a piezoceramic ring-stack driver, metal end plates, a concave metal shell, and a surrounding sphere of seawater. Essentially, when the driver is excited into longitudinal vibrations by an applied electric field, the end plates, acting as stiff mechanical fulcra, force the affixed curved shell into radial vibrations. This in turn causes pressure variations in the adjacent seawater medium and low-frequency audible sound is radiated. Owing to the small size of the transducer relative to the acoustic wavelength of the sound produced at resonance, the radiation pattern is omnidirectional.

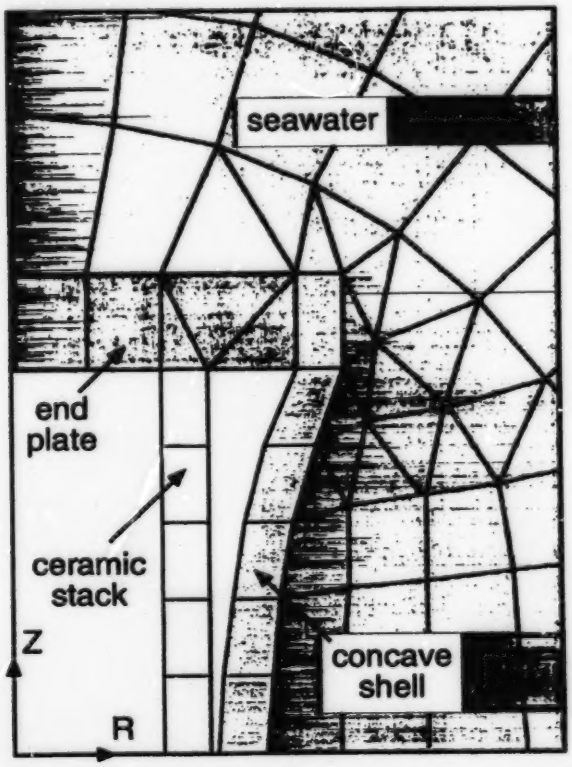

Figure 2. A 2D finite element grid for a barrel-stave flextensional transducer.

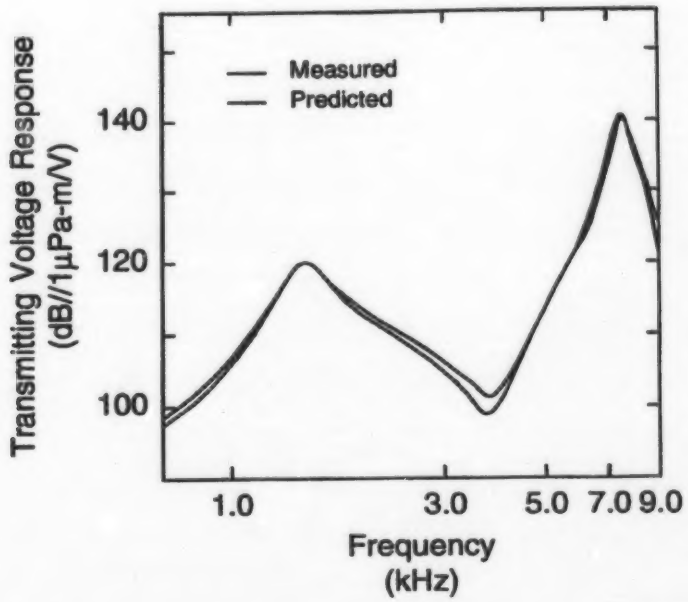

Figure 3. Predicted and measured transmitting voltage response curves.

A number of geometric and material properties approximations are required to relate these axisymmetric finite element models with ∞-fold symmetry to practical devices that have n-fold symmetries, where n is typically an integer that is less than 12. For example, most DREA barrel-stave flextensional transducers have n=8. Thus, the solid concave finite element shell must simulate eight curved staves and the circular end plates in the model must simulate octagonal end plates. These simulations are accomplished by assuming an anisotropic material for the shell finite elements and equal cross-sectional areas for the plates.

An example of the measured versus finite element analysis predicted transmitting voltage response (TVR) curves is shown in Figure 3 for a small experimental barrel-stave flextensional transducer that resonates at 1460 Hz in its fundamental flexural mode [4, 8]. The agreement is quite satisfactory at both the flexural resonance and the extensional resonance, the latter occurring at 7400 Hz.

The 800 Hz barrel-stave flextensional transducer was scaled in size by a factor of 2 from this finite element model. Notable scaling exceptions were the volume of the ceramic driver and the geometry of the staves. In the former case, readily available lead zirconate titanate (PZT) ceramic rings were used that had a volume that was approximately 30% more than the scaled volume (8x). In the latter case, the width, radius of curvature, and thickness of the staves were adjusted to tailor the in-water resonance frequency to about 800 Hz while maintaining a 1 mm gap width between staves. This is the same gap width for the smaller barrel-stave transducers and was used in order to maximize the radiating surface area of the large staves.

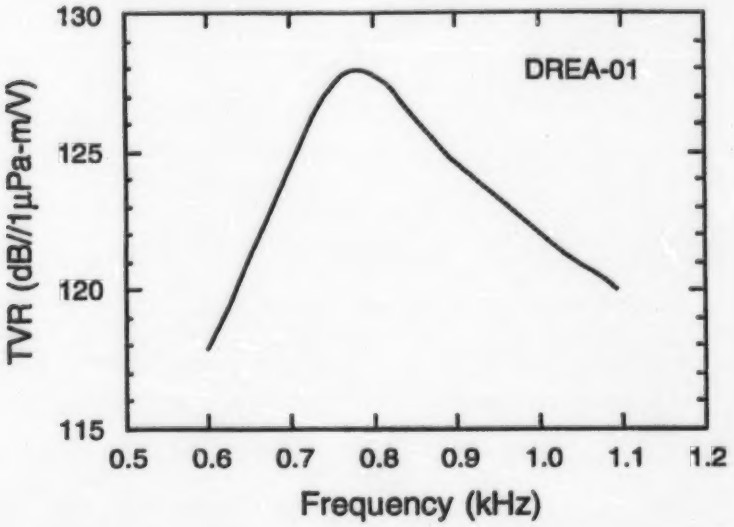

Figure 4. Measured TVR for the 800 Hz prototype barrel-stave transducer.

A prototype transducer, designated DREA-01, was built and tested at DREA in 1991. It had a mass of 16.7 kg which corresponds to the scaled mass (8x) plus excess piezoceramic. The measured TVR curve for the scaled barrel-stave flextensional transducer prototype is shown in Figure 4. This curve was obtained at the DREA Acoustic Calibration Barge on Bedford Basin with the transducer immersed in 30 m of seawater. The resonance frequency was 780 Hz and the mechanical quality factor was 4.5. When driven with an electric field of 2.5 kVrms/cm (6.4 Vrms/mil), the source level was 199 dB//1µPa-m. These parameters are included in Table 1.

Eleven additional 800 Hz experimental transducers were tested during the period 1993-1996 for in-house, low-frequency underwater research. A summary of their high-power performance parameters obtained at 30 m depth is also given in Table 1. The source levels were obtained by applying electric fields of 2.5 kVrms/cm (6.4 Vrms/mil). Omnidirectional radiation patterns were obtained at resonance with a mean directivity index of 0.25 dB. The resonance frequency of DREA-01 is lower than the others since it has thinner aluminum staves [9]. Further discussions of the measured performance parameters for some of the transducers listed in Table 1 are given in the reference list at the end of the report.

Some of the experimental 800 Hz barrel-stave transducers listed in Table 1 have been used at sea by DREA researchers on a regular basis for almost five years in support of in-house underwater acoustical studies. The two deployment techniques that have been developed include mounting the transducer on the back of the DREA towable moving coil projector sled as shown in Figure 5, and mounting the transducer and its transformer in their own simple framework as shown in Figure 6. In both deployment cases the barrel-stave transducers have been directly exposed to the seawater environment for extended periods of time without suffering any adverse effects.

Table 1. Measured parameters for DREA 800 Hz barrel-stave transducers.

Transducer	Frequency (Hz)	Source Level (dB//1μPa-m)	Quality Factor
DREA-01	780	199	4.5
DREA-02	800	200	4.5
DREA-03	800	201	4.5
DREA-04	800	200	4.3
DREA-05	810	201	4.6
DREA-06	830	200	3.9
DREA-07	830	199	3.9
DREA-08	830	201	4.4
DREA-09	830	200	3.9
DREA-10	820	200	4.1
DREA-11	820	199	4.1
DREA-12	830	199	3.9

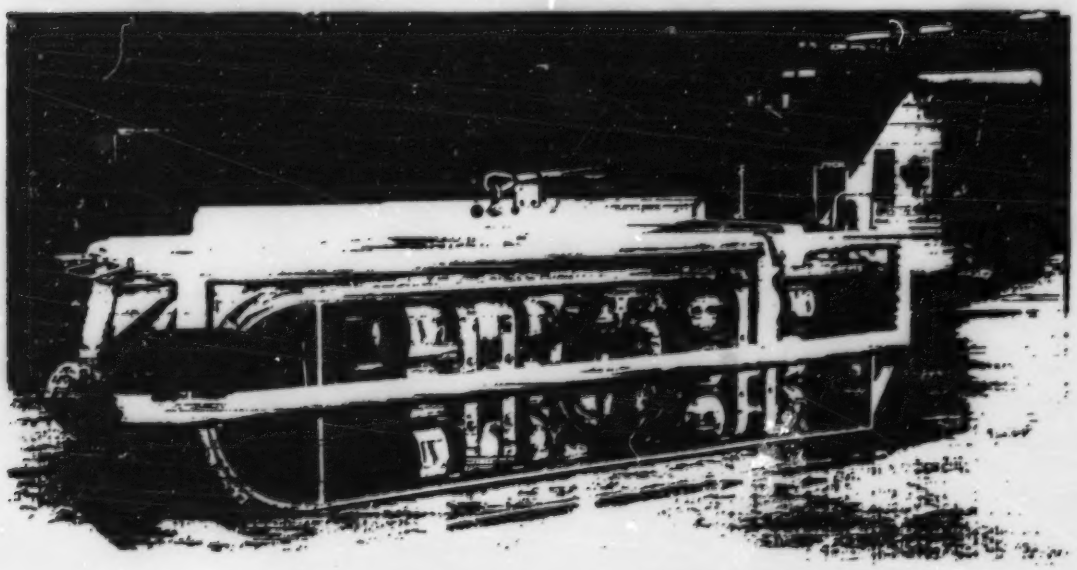

Figure 5. Moving coil and barrel-stave transducer towbody tandem. (Courtesy of Cary Risley and Bob Reynolds)

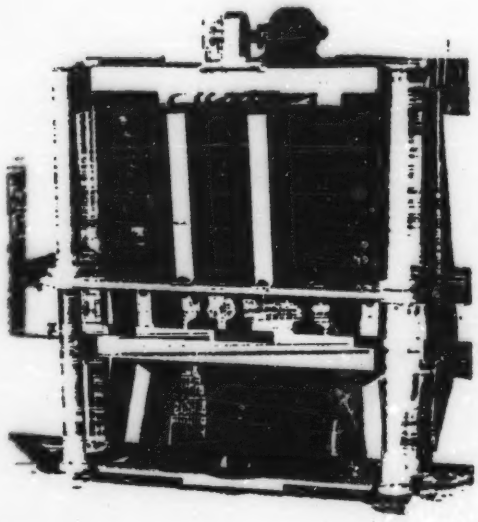

Figure 6. Deployable barrel-stave flextensional transducer framework. (Courtesy of Garry Heard and Bob Reynolds)

4. Collaborative Research

The electroacoustic performance of the 800 Hz barrel-stave flextensional transducer was further investigated through independent collaborations with the Naval Undersea Warfare Center (NUWC) in New London, Connecticut, and Weidlinger Associates Inc. in New York. The 1992 DREA-NUWC collaboration studied the acoustic performance of the transducer at greater water depths and higher driving fields than those available at the DREA Acoustic Calibration Barge while the 1996-97 DREA-Weidlinger collaborations studied the acoustic performance of the transducer using finite element analysis models.

4.1 Measurements

Joint DREA-NUWC calibration measurements on the DREA-01 prototype barrel-stave transducer took place at the NUWC Seneca Lake sonar test facility in Dresden, NY. The transducer was tested at four water depths, namely 30.5 m (100 ft), 61.0 m (200 ft), 91.4 m (300 ft), and 123.4 m (405 ft). Furthermore, the transducer was driven with a wide range of electric fields from 71 Vrms/cm (0.18 Vrms/mil) to the generally accepted piezoceramic field limit of 3930 Vrms/cm (10 Vrms/mil) [10]. For comparative purposes, examples of the key measured performance parameters for the prototype transducer from Bedford Basin and Seneca Lake are given in Table 2.

Table 2. Prototype performance comparison: Bedford Basin versus Seneca Lake.

Depth (m)	Field (Vrms/cm)	Frequency (Hz)	Source Level (dB//1μPa-m)	Quality Factor	Efficiency (%)
Bedford Basin, Nova Scotia, Canada					
30.0	2500	780	199	4.5	–
Seneca Lake, New York, United States					
30.5	2840	780	201	3.9	85

Table 3. Performance summary of various PZT-driven flextensional transducers.

Transducer ID	Frequency (Hz)	FOM_m (W/kg-kHz-Q)	FOM_v (W/m^3-Hz-Q)
Experimental transducer			
DREA-01	790	47	162
Commercial transducers			
Sparton Model 34SA0400	400	55	81
Sparton Model 18SI0700	700	25	71
Sanders Model 30	1030	25	61
Sparton Model 03BA1100	1100	19	50
Edo Model 6993	1560	14	49
Allied Signal Model DX835	2500	30	64

The performance of the DREA-01 800 Hz barrel-stave flextensional transducer has been compared to various commercial PZT-driven flextensional transducers using projector mass and volume figures of merit, denoted FOM_m and FOM_v respectively [11]. These quantities are independent of scaling and reflect the desire to obtain high power, low resonance frequency, and broad bandwidth from a compact and lightweight transducer. These figures of merit are defined as follows:

$$FOM_m = \frac{\text{radiated power (W)}}{\text{mass (kg)} \times \text{frequency (kHz)} \times \text{quality factor}},$$

$$FOM_v = \frac{\text{radiated power (W)}}{\text{volume (m}^3\text{)} \times \text{frequency (Hz)} \times \text{quality factor}}.$$

Table 3 lists the resonance frequencies and figures of merit for the DREA-01 experimental barrel-stave transducer as well as six commercial PZT transducers including Sparton Models 34SA0400 and 18SI0700 ring-shells, a Sparton Model 03BA1100 barrel-stave, a Sanders Model 30 Class IV, an Edo Model 6993 barrel-stave, and an Allied Signal Model DX835 Class IV. The DREA-01 transducer power was measured at Seneca Lake in 61.0 m of water with a driving field of 3930 Vrms/cm (10 Vrms/mil). Clearly from a performance perspective, DREA-01 compares well with the commercial transducers.

4.2 Modelling

Detailed numerical analyses of the electroacoustic performance of the 800 Hz barrel-stave flextensional transducer have been carried out through collaborations between researchers at DREA and Weidlinger Associates Incorporated. Using Weidlinger's PZFlex finite element analysis program, it was possible to develop a 2D axisymmetric model of the transducer to investigate its electroacoustic parameters in water [12, 13].

The geometry of the model is illustrated in Figure 7. Included in the model are a stack of piezoceramic rings, two steel end plates, two aluminum end caps, an aluminum shell, and an epoxy potting. Since the model is axisymmetric, the shell properties are assumed to be anisotropic in order to simulate eight staves. The surrounding water is not shown and damping is not used.

This finite element model was used to analyze the in-water electrical impedance, the transmitting voltage response, and the vibrational modes of the DREA-01 prototype barrel-stave transducer. A separate model of the ring-stack alone permitted the analysis of the in-air electromechanical behaviour of the driver.

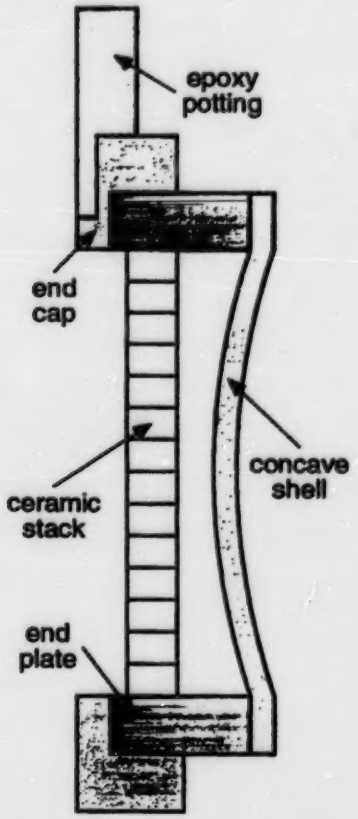

Figure 7. 2D geometry for the 800 Hz barrel-stave flextensional transducer.

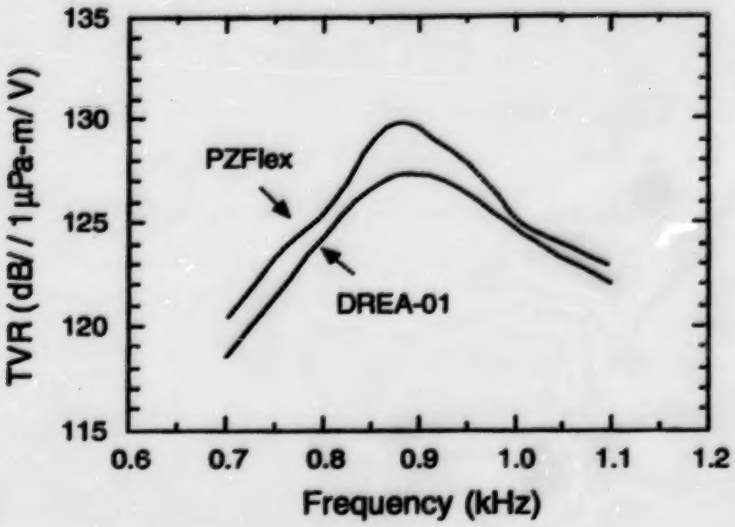

Figure 8. Predicted and measured TVR curves for DREA-01.

An example of the finite element results is given in Figure 8. The measured TVR (black curve) for the prototype DREA-01 barrel-stave flextensional transducer was obtained at the DREA Acoustic Calibration Barge in 14.6 m of seawater. The resonance frequency was 890 Hz and the TVR value at resonance was 127.4 dB//1µPa-m/V. This curve was measured when the transducer had thick aluminum staves. Note that the parameters in Table 1 for this transducer were measured after the staves were machined thinner [9].

The PZFlex finite element model predicts a TVR for the DREA-01 transducer that is given by the red curve in Figure 8. The predicted resonance frequency and the TVR at resonance are 880 Hz and 129.8 dB//1µPa-m/V respectively. The 2.4 dB difference in TVR between measurement and the finite element prediction is most likely due to the fact that the model does not include losses of any kind.

5. Technology Transfer

The DREA 800 Hz barrel-stave flextensional transducer was transferred to Sparton of Canada by early 1996. Their commercial version, designated Model 06BA0800, is shown in Figure 9. With few exceptions, this transducer is essentially the same as the DREA experimental units. Two significant differences are visible in the figure. First, a rubber reinforced neoprene boot was used in order to enhance the performance stability of the transducer with water depth. Eight rubber ridges provide reinforcement over the areas of the gaps between the metal staves. Also, a gas valve has been inserted at the bottom of the transducer and is used for a nitrogen gas depth compensation system.

Measurements of the parameters for the uncompensated Model 06BA0800 unit were carried out at Seneca Lake. A TVR curve obtained at a depth of 122 m (400 ft) with a driving field of 2.2 kVrms/cm (5.6 V/mil) is shown in Figure 10. The resonance frequency was 820 Hz and the TVR at resonance was 127.4 dB//1µPa-m/V [14].

Figure 9. Sparton Model 06BA0800 barrel-stave flextensional transducer. (Courtesy of Sparton of Canada Limited)

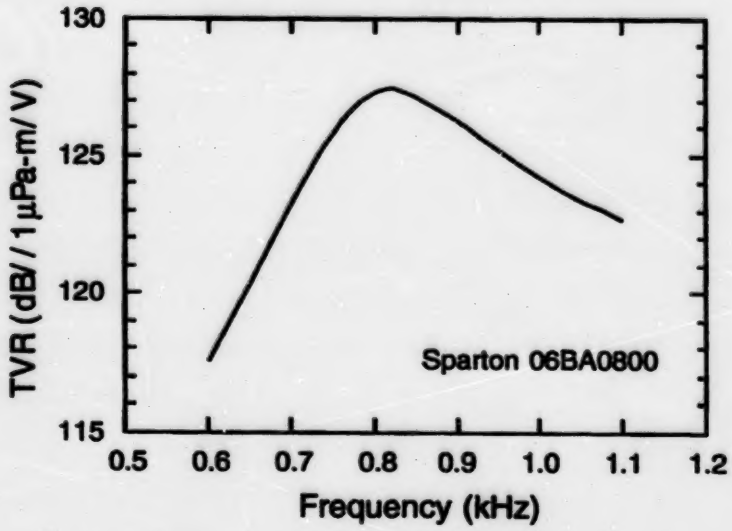

Figure 10. Measured TVR for the Sparton Model 06BA0800. (Courtesy of Sparton of Canada Limited)

In 1996, the Sparton Model 06BA0800 barrel-stave projector just discussed was sold to the Defence Science and Technology Organisation (DSTO) in Australia as one of a suite of high power sonar projectors housed in a deployable towbody. The overlapping frequency bands of the different projectors in the suite give the system an effective frequency band of 50 Hz to 10 kHz. A photograph showing the interior of the DSTO towbody, known as the Sonar Research Projector (SRP), is presented in Figure 11. A second photograph showing the SRP being recovered during a sea trial is presented in Figure 12.

The main components inside the SRP towbody are identified here by starting with the barrel-stave flextensional transducer at the top and center of the body and then moving around the interior in a clockwise direction. Protruding down from the upper fiberglass dome and behind the towpoint is the Sparton Model 06BA0800 barrel-stave transducer (only the bottom half of the transducer can be seen). This transducer is used over the entire frequency range 600-1500 Hz. Located to the right is a cylindrical canister called the Electronics Interface Module (EIM). This module houses various sensors that monitor depth, temperature, pitch, roll, and acceleration, as well as a sensor data transmitter that sends sensor data up the tow cable, preamplifiers for two monitoring hydrophones, and the tow cable interface unit. Below the EIM is a nitrogen-filled scuba tank for the barrel-stave transducer depth compensation system. To the left of the scuba tank is a Sparton Model 18SA0350 ring shell flextensional projector [15] which covers a frequency band below that of the barrel-stave transducer. Immediately above the ring shell projector is a Sparton Model 18FA1800 free flooded ring projector [16] which covers a frequency band above that of the barrel-stave transducer. Located to the left of the ring shell projector are two transformers (side by side) for the ring shell and free-flooded ring projectors. The transformers for the barrel-stave projector and a spherical transducer are located side by side and to the left of the free-flooded ring. The spherical transducer is used for the highest frequency band and is hidden under the upper fiberglass dome and forward of the towpoint. In the center of the towbody is a near-field monitoring hydrophone. A far-field monitoring hydrophone is hidden under the upper fiberglass dome.

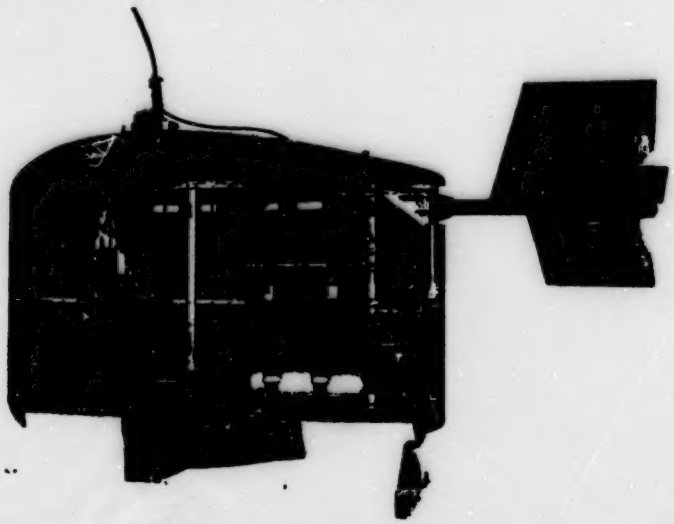

Figure 11. The DSTO Sonar Research Projector towbody.
(Courtesy of Sparton of Canada Limited)

Figure 12. Recovery of the Sonar Research Projector towbody. (Courtesy of the Defence Science and Technology Organisation)

6. Summary

The DREA 800 Hz barrel-stave flextensional transducer evolved from the in-house finite element computer models of the 1980s, to the construction of the prototype in 1991, and finally to the commercial unit made by Sparton of Canada in 1996 and designated Model 06BA0800. The bulk of the research was carried out at DREA as well as through collaborations with the Naval Undersea Warfare Center and Weidlinger Associates Incorporated in the United States. Also in 1996, the Sparton Model 06BA0800 transducer was delivered to the Defence Science and Technology Organisation in Australia as a transducer component in their broadband Sonar Research Projector towbody.

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Since 1991 there have been a number of people who have made significant contributions to the research and development of the 800 Hz barrel-stave transducer. The author would like to thank all of them for their efforts. First is the tireless effort of Charles Reithmeier (DREA) who has single-handedly assembled and tested all of the DREA units in the Transducer Laboratory. The calibration measurements on all of the DREA units were carefully made by Glen Stewart (DREA) at the Acoustic Calibration Barge. The metal components for all of the transducers were skillfully manufactured by Ron Fox (DREA) and his staff in the DREA Model Shop. Finally, the collaborative work and discussions between the author and Mark Moffett (NUWC), Linas Siurna (Sparton of Canada), and Najib Abboud (Weidlinger Associates) were insightful and most gratifying.

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The Defence Research Establishment Atlantic (DREA) barrel-stave flextensional transducer is a compact underwater sound source that is well-suited for high-power low-frequency sonar applications. Various configurations of this transducer were modelled in the 1980s using finite element analysis techniques. A scaled-up version of one of these models was used to design an 800 Hz barrel-stave transducer prototype that was built and tested in 1991. Good performance parameters were obtained for the prototype and by 1996 a number of additional units were built for in-house research purposes. Some of these transducers have performed flawlessly during many DREA sea trials over the last five years. More comprehensive measurements and modelling analyses were done on the 800 Hz prototype through international collaborations with researchers at the Naval Undersea Warfare Center in New London, CT (now consolidated in Newport, RI), and Weidlinger Associates Incorporated in New York, NY. Since the measured acoustic performance parameters for the 800 Hz experimental transducers compare well with the parameters of commercially available piezoelectric flextensional transducers, the technology was transferred to Sparton of Canada Limited in 1996 and has been designated Sparton Model 06BA0800. In the same year the Model 06BA0800 was sold to the Defence Science and Technology Organisation in Australia as one of four active sources in a broadband deployable sonar system known as the Sonar Research Projector towbody. The purpose of this report is to document the history of this flextensional transducer by assembling a mosaic of examples from the various research and development activities that have taken place since 1991.

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